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Description

Semi-conductor element with lattice-mismatched semi-conductor materials

The invention relates to a semi-conductor component in which a first semi-conductor material with a first lattice constant is combined with a second semi-conductor material with a second lattice constant in one and the same semi-conductor body, and the first and second lattice constants differ.

Such a semi-conductor component with lattice-mismatched semi-conductor layers in which a junction from a first semi-conductor layer with a first lattice constant to a second semi-conductor material with a second lattice constant in one and the same semi-conductor body is provided is known from Fan Y. et al., Appl. Phys. Lett. 61 (26), December 28, 1992, 3160 – 3162, for example. This describes a contact scheme for LED's and laser diodes for which the junction from a p-ZnSe layer to a p-ZnTe layer is created by means of a so-called pseudograded Zn (Se, Te) contact layer.

This pseudograded Zn (Se, Te) contact layer consists of a number of ZnSe and ZnTe layers, whereby ZnSe and ZnTe alternate, and the thickness of the ZnSe layers decreases toward the ZnTe side while the thickness of the ZnTe layers increases. This structure is used to maintain an ohmic contact with the p-ZnSe layer with low electrical resistance.

The use of ZnTe layers causes creation of mechanical tension that places a strong mechanical load on the component because of the enormous lattice mismatch to ZnSe within the semi-conductor body. Relaxation of the layers under this load causes offsets and defects that often have a strong negative effect on the optical, electrical, and crystalline characteristics.

The tensions within the semi-conductor body often lead to degradation of the entire component.

A combination of semi-conductor materials with different lattice constants is desirable if the problems that arise in one of the two semi-conductor materials can be thus overcome.

For example, the susceptibility to doping of one of the two semi-conductor materials might be significantly less than that of the other. A junction from one material to the other within the semi-conductor body is then particularly advantageous.

A combination of semi-conductor materials with different lattice constants is also desirable in cases in which a connection may be established that lies between those of the output materials in their characteristics. For example, the doping susceptibility or the band gap may be varied over a wide range in ternary combinations.

Further, contact between a semi-conductor material and metal often leads to a non-ohmic, i.e., rectifying, electrical contact. The reason for this is a voltage barrier that forms at the interface surface between the semi-conductor material and the metal, forming an obstacle for electrons and holes that are supposed to flow from the metal into the semi-conductor material or vice versa. High voltage barriers of this type arise when the electron affinity of the metal and the semi-conductor differ widely.

If, for example, a metallic contact is mounted on a p-conducting ZnSe layer within a semi-conductor component, this voltage barrier arises because electrons are transferred from the metal possessing a lower electron affinity (this applies to the same extent for all known metals) into the semi-conductor, and there reduce the p-doping in accordance with the law of mass action. Thus, the valence band edge is bent away from the Fermi level, and a barrier arises. The barrier hinders the current flow of holes and electrons.

ZnSe may be doped with nitrogen up to a maximum amount of 2×10^{18} cm^{-3} under optimum conditions. This would allow an ohmic contact of up to a barrier level of less than 0.6 eV. The metal with the lowest barrier to ZnSe is Palladium. The level of the voltage barrier in this case is about 0.9 eV. For such a barrier level, however, a low-ohmic contact may be expected beginning at a doping level of about 1×10^{19} cm^{-3}. The disparity of the named parameters shows that it is not possible to achieve a low-loss contact with p-ZnSe using metals alone.

Such problems arise not only in the ZnSe system, but also with various III-V bond semi-conductors, for example.

The task of this invention is to develop a semi-conductor component of the type mentioned initially that exhibits reduced mechanical tension within the semi-conductor body.

This task is solved by a semi-conductor component possessing the characteristics of Claim 1. Advantageous embodiments of the semi-conductor component are the subjects of Sub-claims 2 through 6.

Voltages in the semi-conductor body may be held so low that the mechanical tensions affecting the lattice-mismatch at the edges of several thin, sub-monolayer islands separated from one another and embedded into a formation of a matrix of the first semi-conductor material may be reduced.

By means of these measures, the negative effects of large lattice-mismatch may be largely or completely disregarded even in a combination of materials with largely varying lattice constants.

Sub-monolayer islands may be understood as layers of semi-conductor material that do not cover the entire growth surface of the semi-conductor body basically available for the growth processes of the layers, but rather only a portion thereof.

In an advantageous embodiment of the invention, the second semi-conductor material is more highly doped than the first, whereby the doping material concentration of the entire layer is advantageously increased.

The sub-monolayer islands are advantageously arranged in levels whose separation from one another decreases towards the main surface of the semi-conductor body. Thus, the doping of the semi-conductor body may be advantageously increased in the direction of the surface, for example, if the first semi-conductor material is more poorly doped than the second.

The last layer of the semi-conductor body may be a thin, surface-covering layer of the second semi-conductor material that is formed, for example, as a contact of several layers of different metals. If the thickness of the final layer is sufficiently low (approximately 5 nm for ZnTe, for example), it possesses no negative effects on the layers positioned under it.

The invention is described in greater detail using an embodiment example in combination with Figures 1 and 2 as follows:

Figure 1 shows a schematic view of a vertical cross-section through the embodiment example perpendicular to the semi-conductor layers, and

Figure 2 shows a diagram in which the doping level of the embodiment example in Figure 1 is schematically represented for the depth of one layer.

Figure 1 shows the p-side of a semi-conductor body 3 for which a second semi-conductor layer 10 that includes a matrix 4 made of the same semi-conductor from which the first semi-conductor layer 9 is made, and into which a large number of sub-monolayer islands 5 of a second semi-conductor material 2 is embedded, is superimposed on a first semi-conductor layer 9 made of a first semi-conductor 1, p-ZnSe in the embodiment example.

The sub-monolayer islands 5 in the case of p-ZnSe with matrix material that may be doped only up to a maximum doping level of 2×10^{18} cm^{-3} consist of p-ZnTe that may doped to a significantly higher level. Thus, the electrical resistance determined by the voltage barrier at the junction from the second semi-conductor layer 10 to a p-metal contact on the semi-conductor body is significantly reduced.

The increase of the doping level made possible by this configuration of the p-side toward the main surface 7 of the second semi-conductor layer 10 is shown by the diagram in Figure 2. In this diagram, the y-axis represents the doping level in cm^{-3}, and the x-axis shows the layer depth from main level 7. The layer depth is given without units.

In the embodiment example, a layer 8 covering the entire surface 7 made of the second semi-conductor material is mounted on the main surface 7 of the semi-conductor body 3, and is so thin that it does not detract from the lower layers 9 and 10. This thickness is advantageously about 5 nm for the ZnSe/ZnTe system.

This layer 8 is not absolutely required, however, for the basic advantageous effect of the invention.

In the above-described embodiment example, a ZnSeTe matrix with 2% to 10% Te may be used instead of the matrix 4 of ZnSe, for example.

The matrix 4 containing the embedded sub-monolayer islands 5 may be produced using the following procedure, for example:

- Production of the first semi-conductor layer 9 consisting of the first semi-conductor material 1;
- Placing several sub-monolayer islands 5 consisting of the second semi-conductor material 2 onto this first semi-conductor layer 9;
- Emplacing a first matrix layer consisting of the first semi-conductor material 1 that is thicker than the sub-monolayer islands 5;
- Placing several sub-monolayer islands 5 consisting of the second semi-conductor material 2 onto the first matrix level;
- Emplacing a second matrix layer consisting of the first semi-conductor material 1 that is thicker than the sub-monolayer islands 5 and thinner than the first matrix layer;
- Etc.

This principle based on the invention is not limited, of course, to this embodiment example, but may be applied anywhere that semi-conductor materials possessing varying lattice constants are to be combined. The principle allows a simple method of combining weakly-doped or dopable material with a highly-doped or dopable material, even if the lattice-mismatch between both materials is great.

Semi-conductor components based on GaN [are[1]] used as an example.

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[1] Translator's Note: "seinen" (his) is probably a typo for "seien" (are).